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The Role and Importance of the Arctic and its Sea Route in International Economic Relations

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Abstract

The Arctic region, long known for its harsh climate and remoteness, is increasingly seen as a critical area for future economic growth due to its vast natural resources and strategic geopolitical importance. This study analyses the Arctic's economic potential and the associated geopolitical, legal, and environmental challenges arising from its resource exploitation. We performed a statistical review of Arctic energy resources, particularly oil and gas, along with a comparison of territorial claims and interests of countries like the United States, Canada, Norway, and Denmark. The findings highlight the Arctic's significant economic value due to its natural resources and emerging transportation routes, such as the Northern Sea Route, which could reduce transportation costs and enhance trade between Europe and Asia. However, these opportunities are accompanied by challenges, including extreme climatic conditions, high infrastructure costs, and complex legal disputes over territorial boundaries and resource access. The study emphasizes the need for effective international cooperation to regulate resources and prevent conflicts over Arctic claims. It also advocates for a balanced approach to development, ensuring that economic growth is aligned with environmental protection and peace in the region. A coherent international policy framework is essential for managing Arctic resources, addressing environmental concerns, and ensuring sustainable development without compromising the region's natural integrity.

Keywords

Northern Sea Route; Transport infrastructure; Geopolitical stability; Energy resources; Sustainable development

Introduction

The Arctic, rich in natural resources and strategically positioned between Europe and Asia, has become a focal point in global economic discussions. With the reduction in ice cover facilitating new sea routes and access to previously untapped resources, the

region offers significant opportunities for economic development. However, these opportunities are accompanied by serious risks and challenges. Among the most pressing are the legal and geopolitical conflicts over territorial claims, as well as environmental concerns related to resource extraction and climate change.

The Arctic's natural resources, including up to 13% of the world's oil reserves and 30% of undiscovered natural gas, have made it a critical area for energy security, not only for Arctic-bordering nations but also for major powers such as China, which are increasingly pursuing interests in the region (DeWitt *et al*., 2020). Moreover, the Northern Sea Route (NSR) has the potential to reduce transportation costs between Europe and Asia by up to 40%, offering a strategic alternative to traditional maritime pathways. However, despite these opportunities, the region is fraught with numerous conflicts, particularly regarding the legal regulation of the Arctic continental shelf. Researchers such as Buckley (2023) highlight that the lack of a unified international framework for distributing resource rights and defining borders has led to tensions, especially between Russia, Canada, and Norway.

Legal disputes over territorial boundaries are further complicated by differing national interests and interpretations of international law. Russia, for example, asserts extensive claims over the Arctic shelf based on geological research, a position that is contested by neighbouring countries like Norway and Canada. This territorial uncertainty, as noted by Loukacheva (2020), underscores the need for a comprehensive international legal framework that can effectively manage economic activities and resolve disputes over resources.

Environmental risks also play a critical role in Arctic development. The region’s ecosystems, which support unique species, are increasingly vulnerable to the effects of climate change, as identified by Gauthier *et al*. (2021). The combination of resource depletion, rising transportation activity, and changing climatic conditions creates a complex situation where the region’s ecological stability is at risk, with consequences extending far beyond the Arctic. As Larsen and Petrov (2020) argue, the current legal and environmental frameworks are insufficient to balance economic development with the preservation of Arctic ecosystems.

Given these challenges, international cooperation becomes paramount. The evolving role of the Northern Sea Route and the increasing economic significance of the Arctic make it crucial to develop mechanisms that promote responsible resource use while maintaining environmental and geopolitical stability. This study explores the Arctic’s potential for the global economy, focusing on the key legal, geopolitical, and environmental challenges that must be addressed for its sustainable exploitation. The objectives of the study are as follows:

- to examine the geopolitical and legal challenges associated with the Arctic’s exploitation, particularly in relation to territorial disputes, international legal frameworks, and national claims on the Arctic continental shelf;
- to analyse the environmental risks of resource extraction and transportation in the Arctic, evaluating the ecological impacts of increased activity in the region, including biodiversity loss and climate change;
- evaluate the role of the NSR as an alternative shipping route between Europe and Asia, and assess its potential to reduce transportation costs and improve

global trade efficiency;
- propose policy recommendations for sustainable development in the Arctic, emphasizing the need for international cooperation, responsible resource management, and protection of Indigenous rights and ecosystems.

Methodology

Research Scope

This study was conducted between January 2020 and October 2024 to assess the economic significance of the Arctic region in international economic relations, explore its potential contributions to the global economy, and analyse the economic, legal, and geopolitical challenges associated with its exploitation. The research methodology incorporated a multi-faceted approach, combining statistical data analysis, comparative assessment of territorial claims, and examination of international legal frameworks governing Arctic resources.

Data Collection

Data collection was structured around several key dimensions. First, information on Arctic natural resources, including oil, gas, fisheries, and mineral deposits, was gathered from national reports, international databases, and scientific literature. Secondary sources included governmental reports from Arctic-bordering states such as Iceland, Norway, Canada, and the United States, as well as documents from the Arctic Council. Comparative data spanning 2016, 2018, 2020, and 2022 were examined to evaluate fluctuations in resource availability and extraction trends (Evans, 2024). Additionally, energy security and resource sustainability were analysed based on reports from international organisations and academic publications (Hansen and Tàbara, 2024).

Transportation Infrastructure Analysis

The assessment of the Arctic's economic prospects was conducted through a comparative analysis of its transportation infrastructure, particularly the Northern Sea Route, as an alternative to the Suez Canal. Factors such as transportation time, fuel costs, icebreaker dependency, and overall efficiency were evaluated using data from port infrastructure reports from Tromsø (Norway) and Reykjavik (Iceland) (Lundgren, Löfving and Westin, 2023). Climate data affecting route accessibility, such as seasonal ice melt and sea level changes, were integrated into the analysis (Marten, 2023).

Legal Framework and Geopolitics Analysis

For the legal analysis, key international agreements, including the United Nations Convention on the Law of the Sea (1982), were examined in conjunction with policy documents from the Arctic Council and national legal frameworks of Arctic states (Heininen *et al*., 2020). The study focused on maritime border disputes and the legal basis for territorial claims, particularly applications submitted to the Commission on the Limits of the Continental Shelf by Canada, Norway, the United States, and Iceland (Friedman and Smith, 2024).

The geopolitical analysis considered strategic interests in Arctic resource exploitation, focusing on tensions between Arctic and non-Arctic states, such as China's increasing economic and political engagement in the region. This aspect was investigated through reports from international organisations and government statements (Barry *et al*., 2020a, 2020b).

Environmental Impact Assessment

To assess environmental implications, data from the Intergovernmental Panel on Climate Change (IPCC) were used to evaluate the impact of Arctic resource extraction and transportation activities on climate and biodiversity. Key factors included ice sheet melting rates, sea level rise, and CO2 emissions (Allan *et al*., 2023). The study incorporated an ecological risk assessment of Arctic resource exploitation, particularly in high-biodiversity regions.

Data Analysis

Data analysis was conducted through a mixed-methods approach. Quantitative data on resource availability, extraction volumes, and economic indicators were statistically examined to identify trends and correlations. Qualitative content analysis was employed to examine geopolitical discourse, legal frameworks, and policy responses. The combination of these methods provided a comprehensive understanding of the economic, legal, and environmental challenges associated with Arctic development. This methodological approach ensures a holistic evaluation of the Arctic's economic potential, considering both its opportunities and associated risks. By integrating data from multiple disciplines, the study provides a nuanced perspective on the strategic importance of the Arctic in contemporary international economic relations.

Results

The study showed that the Arctic is a region rich in natural resources that greatly influence the global economy. The most valuable of these are oil, natural gas, minerals, and biological resources. According to estimates, up to 30% of the world's undiscovered natural gas reserves and up to 13% of the world's oil reserves were stored in the Arctic (Friedman and Smith, 2024). The extraction of these resources had an important impact on global energy markets, as the high costs of developing and transporting Arctic deposits led to higher energy prices. It also changed the geopolitical situation, as countries that controlled access to these resources gained strategic advantages in the global energy sphere.

Minerals, including gold, platinum, diamonds, and rare earth metals such as lithium, cobalt, and niobium, have also been important to the Arctic economy. Studies have demonstrated that the extraction of these resources has impacted global markets, as the demand for rare earth metals has risen due to the development of renewable energy technologies and electric car production (Henriques and Böhm, 2022). An increase in the production of these metals in the Arctic could reduce reliance on other regions, such as China and Africa, and result in higher prices for these resources.

Fishing in the Arctic has also been an important element of the global seafood trade. Given the richness of biological resources, such as cod and haddock, the Arctic has been an important supplier of fish products. Climate change and the availability of new fishing grounds would increase production, which would have an impact on seafood prices. However, overfishing and environmental risks could lead to instability in fishing volumes and the value of fish products on world markets.

Tourism would also be an important economic driver for Arctic coastal countries such as Norway, Iceland, and Russia. The reduction in ice cover could stimulate the growth of cruise and eco-tourism, potentially becoming a significant source of revenue for Arctic-bordering countries. However, environmental risks may impede the sustainable development of this sector. At the same time, various countries aim to strengthen their economic and military presence in the Arctic, intertwining with their territorial claims and resource interests, as illustrated in table 1.

Table 1: Interests and territorial claims of countries in the Arctic region

Country	*Claims*
Russia	It owns the largest Arctic territories and is actively strengthening its presence in the region by setting up military bases and developing infrastructure for oil, gas, and mineral extraction. The focus is on exploiting natural resources and enhancing the Northern Sea Route as a key international trade passage. It is involved in territorial disputes with Canada and the United States over control of Arctic waters and sea lanes.
USA	They are trying to balance their concerns about Russian military activity with economic interests in the Arctic. They actively support the development of new technologies for natural resource extraction and investment in climate change research, while simultaneously working to expand their military presence in the region. This is driven by potential threats from Russia and strategic interests in controlling sea lanes and resources, particularly in the context of global competition for energy resources.
Canada	They focus on protecting their territorial claims, especially in the Arctic Archipelago. Canada's concern about Russian and American ambitions has led it to actively promote the ideas of international cooperation and peaceful settlement of disputes through legal mechanisms. Canada also supports the strategy of sustainable development in the Arctic, particularly in fisheries, which is important for its northern territories, and is actively working to preserve the ecological balance in the region.
Norway	They are actively working to increase natural resource extraction in the Arctic, particularly in the Barents Sea. Meanwhile, Norway seeks a peaceful settlement of territorial disputes with Russia, especially in the delimitation of maritime borders. Its interests are also focused on the development of the Northern Sea Route as an alternative route for international trade, which could reduce dependence on traditional routes through the Suez Canal.
China	Although it does not have direct access to Arctic waters, it is actively interested in the region through investments in infrastructure projects

	and the development of sea routes. Its ambitions in the Arctic are driven by a desire to secure access to natural resources and to strengthen its role in the global economy. China actively supports international cooperation through the Arctic Council, but its actions are often perceived as part of a strategy to expand its influence in the Arctic.
Other countries (Sweden, Finland, Denmark and Iceland)	They have a limited territorial presence in the Arctic but are actively engaged in international cooperation on environmental issues and sustainable development in the region. They also back initiatives to protect the Arctic's natural resources and encourage collaborative research to enhance the understanding of climate change and its effects on ecosystems.

Melting glaciers in the Arctic are making previously inaccessible oil and gas fields potentially available for production. Climate change is reducing the amount of sea ice, which makes it possible to expand natural resource extraction activities, including oil and gas, in the high seas. For example, fields in the Kara and Barents Seas are becoming more accessible, which creates opportunities for new investments in the oil and gas industry (Figure 1).

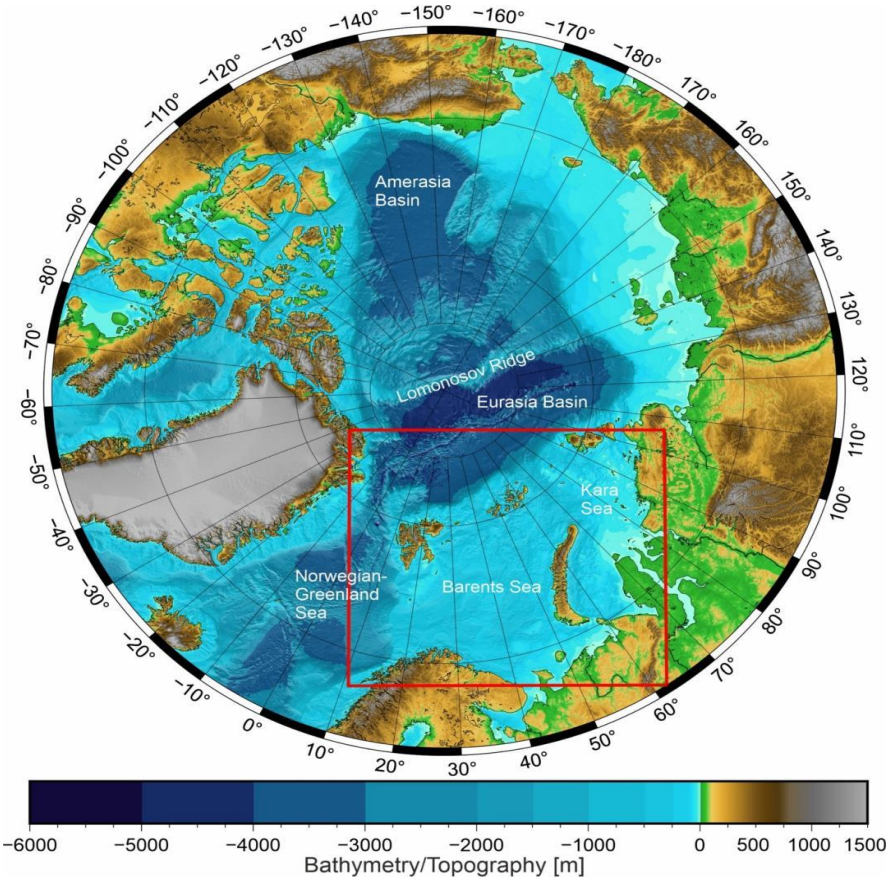

Figure 1: Regional conditions and location of the study area in the Arctic [*Source*: Klitzke (2020)]

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However, this process is also accompanied by high environmental risks, as mining in such a sensitive region can negatively affect ecosystems, including marine life, which can cause global environmental problems. Climate change is also having a significant impact on shipping in the Arctic. Melting glaciers are making previously impassable waters more accessible for shipping. In particular, new sea routes are opening up, such as the Northern Sea Route and the Northwest Passage, which reduce travel time between Europe and Asia (Figures 2 and 3). This can significantly reduce the cost of transporting goods and change global trade routes. For example, the Northern Sea Route, which stretches along Russia's northern coast, could become an alternative to traditional routes through the Suez Canal, reducing travel time between Europe and East Asia by almost 40%. This opens up new trade opportunities, in particular for the export of natural resources such as oil, gas, and metal ores, as well as for the development of shipping in the region (Sur and Kim, 2020).

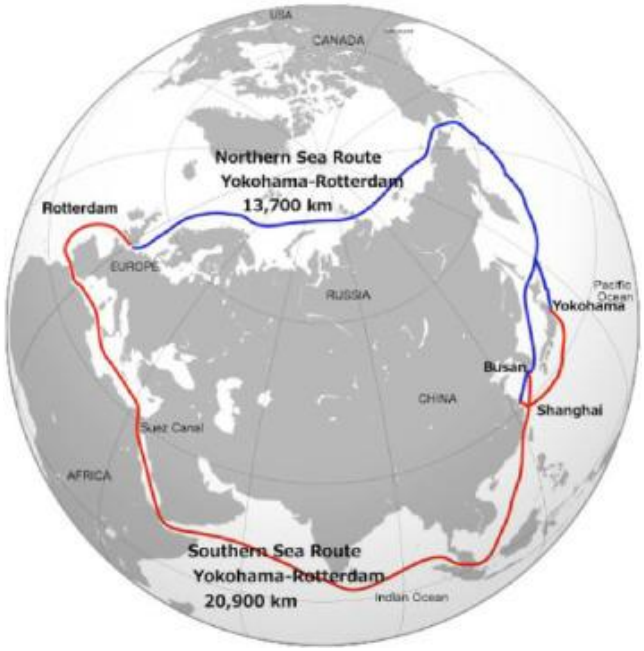

Figure 2: Comparative analysis of the Northern Sea Route and the traditional sea route [*Source*: Sur and Kim (2020)]

Nevertheless, the growing activity in shipping and resource extraction also creates new challenges. Thin ice cover and unpredictable weather conditions can pose dangers to ships passing through these waters, as well as to the development of new oil and gas fields. The risks of accidents and pollution in such extreme conditions are significant, necessitating the development of new technologies for safe navigation and resource extraction. Additionally, the environmental impacts of climate change, such as changes in Arctic flora and fauna, may undermine the sustainability of fisheries and other natural resources, carrying significant economic implications for countries that rely on these sectors.

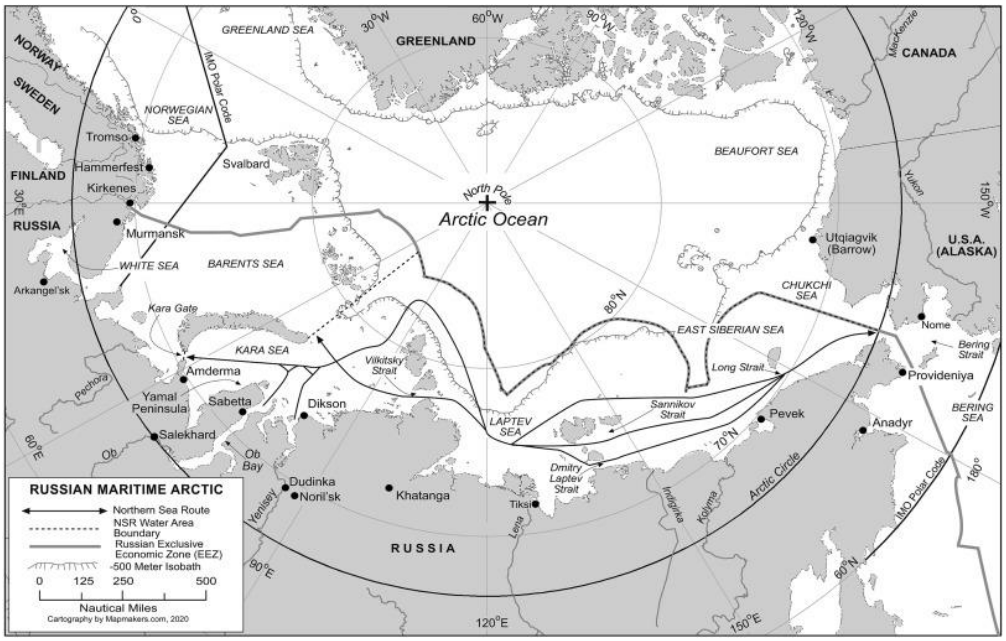

Figure 3: Sea routes passing through the Arctic Ocean [*Source*: Li *et al*. (2021)]

Climate change is also opening up new opportunities for tourism development in the Arctic, as the shrinking ice cover allows access to more of the region. This creates opportunities for cruise tourism and eco-tourism, which could become an important source of revenue for countries with access to the Arctic.

Economic activity in the Arctic is governed by several international legal frameworks aimed at ensuring sustainable development, environmental safety, and peaceful coexistence of states with territorial claims in the region. The main instruments are the Arctic Council (Government of Canada, 2021) and the United Nations Convention on the Law of the Sea (1982). The United Nations Convention on the Law of the Sea is the primary legal framework regulating issues related to maritime boundaries and the use of marine resources, including the Arctic. This agreement establishes rules for the definition of economic zones, continental shelves and territorial waters, as well as rights to extract natural resources such as oil, gas, and minerals. With the help of the United Nations Convention on the Law of the Sea, countries with claims to the Arctic continental shelf can apply to extend their maritime borders, which entitles them to additional resources in these waters. This is especially important for the Arctic as climate change and the melting of ice open up new opportunities for the extraction of resources that were previously inaccessible. While the United Nations Convention on the Law of the Sea is an important tool for regulating many issues in the Arctic, its ability to effectively manage the growing economic activity in the region is limited. This is because the United Nations Convention on the Law of the Sea does not have mechanisms to effectively address new challenges such as climate change, environmental risks from resource extraction, and intensive shipping. In addition, some countries, such as the United States, have not ratified the United Nations Convention on the Law of the Sea, which creates additional legal complications.

The Arctic Council is another key international organisation that helps regulate activities in the Arctic (Government of Canada, 2021). It brings together eight Arctic states: Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, the United States, and the United Kingdom. The Council provides a platform for cooperation on environmental, economic and social issues in the Arctic. One of the main goals of the Arctic Council is to promote sustainable development of the region, environmental protection and protection of the rights of Arctic indigenous peoples.

Although the Arctic Council provides an important platform for diplomacy and cooperation in the region, its mandate is limited mainly to environmental and sustainable development issues. It does not have the legal authority to enforce its decisions, and therefore, its influence on managing the growing economic activity in the region is limited. The Council is, however, active in monitoring climate change and protecting biodiversity, which is important in the context of growing economic activity in the Arctic, including natural resource extraction.

In addition, national legislation and bilateral agreements between countries play an important role in regulating economic activity in the Arctic. For instance, Russia, Canada, and the United States have reached several agreements to define maritime boundaries and jointly manage resources in certain areas (Souhail, 2021). However, given the growing interest in oil, gas, and mineral extraction, along with increased shipping, existing legal frameworks may not be adequate to manage potential conflicts and ensure security.

One of the biggest environmental risks is pollution from oil, gas, and mineral extraction. Because the Arctic has limited self-cleaning capabilities due to low temperatures and slow biodegradation processes, any pollution, such as oil spills or chemical releases, can last for decades.

The Arctic region is a distinctive area abundant in natural resources that are strategically important to the global economy (Atamanenko and Tsvietkov, 2023). Thanks to rich deposits of oil, natural gas, non-ferrous and precious metal ores, along with significant freshwater reserves, the Arctic is increasingly attracting the attention of both governments and international corporations. Despite the harsh climatic conditions and technical challenges, the development of resource extraction in the region is advancing steadily.

Among the most valuable resources of the Arctic are oil and natural gas reserves located in the offshore areas of the Barents and Kara Seas. Russia, Norway and other countries are actively investing in energy production in these areas, using modern technologies for exploration and production. The Arctic is also a source of rare earth elements, which are critical for the development of high-tech industry, and iron ore, which is concentrated in Greenland and Canada. In addition to minerals, Greenland's glaciers hold significant reserves of fresh water, which could potentially become an important resource for water-scarce countries. Table 2 shows data on the production of major natural resources in the Arctic, as well as their distribution by region, major producers, reserves, and production levels. These data allow us to assess the scale of the Arctic's resource potential and its importance for the modern economy.

Table 2: Natural resource extraction in the Arctic

Resource	*Region*	*Main producing countries*	*Estimated reserves*	*Production level*
Oil	The continental shelves of the Barents and Kara Seas	Russia, Norway	13% of the world's reserves	Over 4 million barrels per day
Natural gas	Yamalo-Nenets Autonomous Okrug, Barents Sea	Russia	30% of the world's reserves	More than 600 billion cubic meters per year
Iron	Greenland, Canada	Denmark, Canada	Large deposits	New promising fields discovered
Rare earth elements	Arctic Canada, Russia	Canada, Russia	Unique stocks	Actively developing
Fresh water	Glaciers of Greenland	Denmark	10% of the world's freshwater reserves	Not used industrially

Source: Wiśniewski (2021)

Oil spills are particularly dangerous because they can severely affect marine life, including marine mammals, birds, and fish, which are key links in food chains (Kubiczek *et al*., 2024; Uzenbaev *et al*., 2019). Pollution also threatens valuable Arctic ice, as chemicals can penetrate the icy waters and persist in ecosystems for long periods. As most shipping and mining takes place in the seas and oceans, particularly through the Northern Sea Route, the risk of pollution in these waters is increasing, which can lead to long-term environmental impacts.

Another major environmental challenge is the loss of biodiversity. Changes in Arctic ecosystems associated with melting ice and rising temperatures are creating conditions for the displacement of Arctic species that may not have the ability to adapt to rapid change (Shumka *et al*., 2020; 2023). Warmer waters favour the invasion of new species, such as warm-water fish and predators, which upset the balance of existing ecosystems (Fedonyuk *et al*., 2020). This can lead to the extinction of native species such as Arctic reindeer, polar bears, and other animals that depend on glacial environments. The deterioration of biodiversity can have far-reaching consequences, including changes in food chains and impacts on the livelihoods of indigenous peoples who rely on these resources for their livelihoods (Shuvar *et al*., 2021a, 2021b).

Climate change is one of the primary environmental risks associated with intensive economic activity in the Arctic (Konovalyuk *et al*., 2023). In particular, oil and gas production, which is accompanied by an increase in greenhouse gas emissions, significantly exacerbates the problem of global warming. Expanding natural resource extraction and increasing shipping volumes contribute to a further increase in CO_2 emissions, which negatively affect the climate at the global level (Allan *et al*., 2023).

This, in turn, leads to the deterioration of glaciers, melting sea ice, and rising ocean levels, which can have serious consequences for coastal areas and ecosystems. In this context, there is a need to develop recommendations to mitigate these environmental risks, which will help reduce the negative impact on the environment and preserve the balance of climate processes (Table 3).

Table 3: Recommendations for minimizing environmental risks

Recommendation	*Actions to implement the recommendation*	*Projected impact of the recommended actions*
1. Establishing strict environmental standards and regulations	To put this recommendation into action, national and international laws should be developed and adopted to set mandatory environmental standards for all activities in the Arctic, including mining, shipping, and tourism. It is essential to ensure ongoing monitoring of compliance and impose appropriate penalties for violations	Introducing strict environmental standards and regulations will greatly reduce the negative environmental impact in the Arctic, ensuring sustainable development and the protection of ecosystems
2. Strengthening international cooperation	To put this recommendation into action, diplomatic efforts should be strengthened to reach new international agreements focused on protecting the Arctic. It is essential to establish international platforms for sharing information, research, and best practices, as well as to organise collaborative environmental initiatives among countries with territorial claims in the Arctic.	Enhancing international cooperation will enable effective coordination of efforts to protect the Arctic environment, promoting the exchange of knowledge, resources, and technologies to minimise environmental risks.
3. Increase investment in research and development	For the effective implementation of this recommendation, it is necessary to attract additional financial resources from governments, private companies and international organisations to develop scientific research in the Arctic. It is important to establish specialised research centres, support interdisciplinary research, and ensure data exchange between participants.	Greater investment in scientific research will help us gain a deeper understanding of environmental processes in the Arctic and develop innovative solutions to reduce the impact of human activity on this unique ecosystem.
4. Creation of special environmental zones	To implement this recommendation, it is necessary to identify key Arctic ecosystems that require special protection and establish protected areas on their basis. This includes the development and implementation of legal acts prohibiting or restricting	Establishing special environmental zones will help protect the most vulnerable regions of the Arctic, contributing to the conservation of

Recommendation	*Actions to implement the recommendation*	*Projected impact of the recommended actions*
	activities that may harm these areas, as well as the organisation of proper control over their implementation.	biodiversity and preventing the negative impact of industrial activities on the environment.
5. Use of technologies to reduce greenhouse gas emissions	To implement this recommendation, the development and adoption of technologies that reduce greenhouse gas emissions, such as renewable energy, energy-efficient solutions, and carbon capture systems, should be promoted. Governments should support investments in green technologies through subsidies, tax incentives, and other forms of encouragement	The use of technologies to reduce greenhouse gas emissions will help slow the pace of global warming and minimise the negative impact on the Arctic's climate and ecosystems
6. Ensuring the protection of the rights of indigenous peoples	To effectively implement this recommendation, it is essential to acknowledge the rights of indigenous peoples to land, resources, and traditional practices. This involves creating mechanisms for their involvement in decision-making regarding natural resource use, as well as reinforcing the monitoring and protection of their rights in both international and national law.	Protecting the rights of Arctic indigenous peoples will help preserve their traditional ways of life and culture, while also ensuring their involvement in decisions regarding the use of natural resources and environmental conservation.

Thus, while economic activities in the Arctic create significant opportunities, they also pose serious environmental risks. To minimise these risks, comprehensive strategies must be implemented that balance environmental protection with economic interests, ensuring the long-term sustainability of the region.

Infrastructural development in the Arctic, such as the construction of ports, airports, and pipelines, can have a significant impact on the region's economy and its integration into global supply chains. Due to its strategic location and abundant natural resources, infrastructure investments create new opportunities for economic growth and strengthen connectivity between the continents. This is depicted in Figure 4, which illustrates the development of the Northern Sea Route, an important transportation route that is contributing to the development of transport infrastructure in the region.

The development of cargo traffic along the Northern Sea Route is crucial in shaping the modern transportation infrastructure of the Arctic region. This route, which runs along Russia's Arctic coast, offers a shorter and more cost-effective path for transporting goods between Europe and Asia. The transportation of energy resources, especially liquefied natural gas, is receiving particular focus.

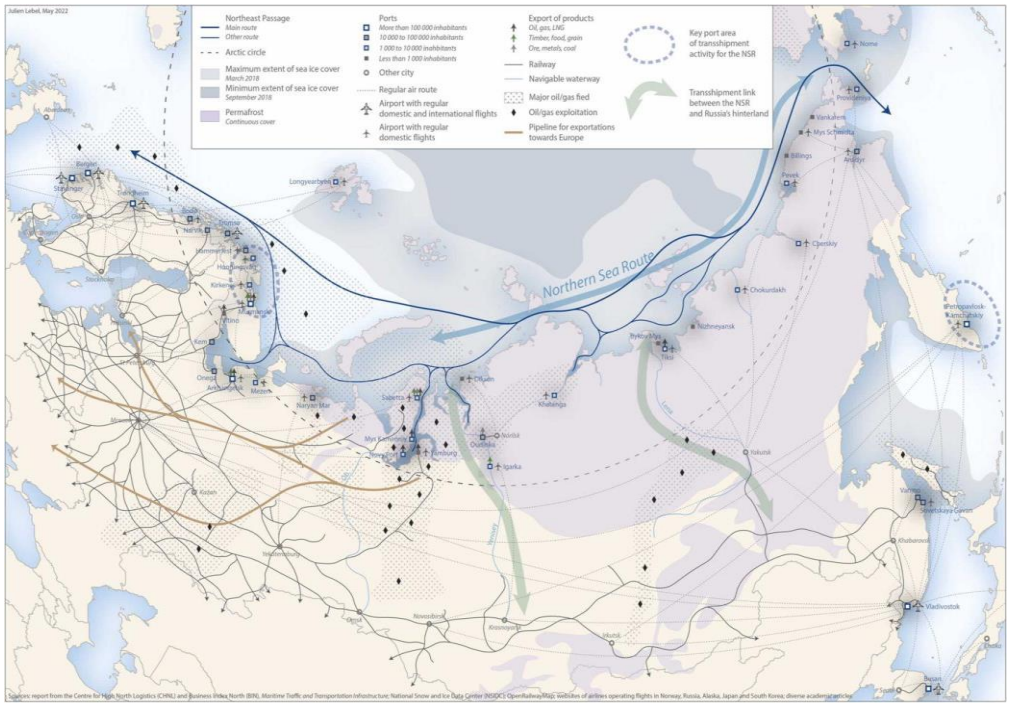

Figure 4: The Northern Sea Route. Transport infrastructure of the area [*Source*: Hermann *et al*. (2022)]

Liquefied natural gas is the main cargo of the Northern Sea Route. It is natural gas, mainly methane, which is cooled to a temperature of -162°C to become a liquid. This makes it easier to transport large volumes over long distances. The main liquefied natural gas export points are the Sabetta ports associated with large-scale projects such as Yamal liquefied natural gas and Arctic liquefied natural gas-2 (Meza *et al*., 2023).

The growth of cargo turnover on the Northern Sea Route is driven by infrastructure investments, including the construction of new nuclear icebreakers, the modernisation of port facilities, and the gradual reduction of ice cover due to climate change. Forecasts until 2030 show a significant increase in traffic, which will strengthen the role of the Northern Sea Route as a key element of the global logistics network (Prentice, Lau and Ng, 2021). Below is the data on the dynamics of cargo turnover at the PIC since 2016, as well as the forecast for 2030 (Table 4).

Table 4: Arctic cargo transportation volumes

Year	*Volume (million tons)*	*The main factors of influence*
2016	7.5	Start of liquefied natural gas infrastructure development
2018	20.2	Start of operations at the Yamal liquefied natural gas plant
2020	32	Record growth due to increased liquefied natural gas exports

Year	*Volume (million tons)*	*The main factors of influence*
2022	34.1	Increase in liquefied natural gas transportation, including 280 voyages from the port of Sabetta
2023	35	A new record is supported by the operation of nuclear icebreakers and plans to expand infrastructure.
2024	80	Increase due to port expansion and new liquefied natural gas projects
2030 (expected)	110	Large-scale growth is planned due to investments in infrastructure and global changes in transportation routes.

Source: Prentice, Lau and Ng (2021)

The data demonstrates a steady increase in cargo turnover due to the active development of the Arctic region. The projected doubling of traffic volumes by 2030 confirms the strategic importance of the Northern Sea Route for international trade, particularly in the energy sector. The development of ports in the Arctic is a key factor in stimulating maritime trade (Nitsenko *et al*., 2017). Expanding port capacities enables the efficient transportation of resources, such as oil, gas, metal ores, and other goods, from the Arctic to international markets. A notable example is the development of ports in northern Russia, which connect Europe and Asia via the Northern Sea Route. This route shortens delivery times by reducing the distance between East Asia and Europe compared to traditional sea routes like the Suez Canal. As a result, transportation costs could decrease, positioning the Arctic as an important transportation hub in global supply chains.

The construction of airports in the Arctic also plays a significant role in the region's development, providing quick access to remote areas for transporting cargo and passengers. Airports are becoming essential for supporting the infrastructure of oil, gas, and mining projects in the region. Moreover, as aviation infrastructure expands, the tourism potential grows, with the Arctic becoming an increasingly popular destination for eco-tourism and cruise activities.

Investments in energy transportation pipelines are also crucial for the Arctic's economic integration into global markets. Pipelines can greatly reduce the cost of transporting oil and gas from the Arctic to other regions, making resource extraction in the area economically viable and competitive. One of the largest projects in this regard is the construction of pipelines to transport gas from Arctic fields to Europe and Asia. This will provide countries with significant resources in the Arctic with a stable demand for energy in international markets.

The development of infrastructure in the Arctic also generates new job opportunities and fosters local economic growth, especially in sectors such as construction, transportation, logistics, and oil and gas. This not only attracts investment but also supports the growth of small and medium-sized enterprises that address local needs and contribute to economic stability.

However, infrastructural development in the Arctic also presents several

challenges (Alvarez, Yumashev and Whiteman, 2020). Given the region's high vulnerability to climate change, environmental factors must be carefully considered in the planning and construction of infrastructure. It is crucial to ensure that infrastructure is designed to withstand extreme weather conditions, such as severe cold, storms, and ice. Furthermore, infrastructure development could intensify geopolitical competition, as nations compete for control over strategic routes, natural resources, and critical infrastructure projects.

The development of the Arctic and the exploitation of its natural resources can have significant social and economic impacts on local communities, including indigenous peoples who have lived in the region for centuries (Table 5). On one hand, resource development can provide economic benefits and improve infrastructure, but on the other hand, it presents several challenges related to cultural, environmental, and social changes.

Table 5: Main consequences of Arctic development

Consequences of Arctic development	*Description*
Environmental impacts	1. Melting glaciers: Rising temperatures can lead to a significant reduction in ice cover, which affects the global climate. 2. Loss of biodiversity: changes in ecosystems, impacts on fauna and flora (especially on ice-dependent species such as penguins and bears). 3. Environmental pollution: mining and oil extraction can lead to water and soil contamination.
Climate change	1. Rising sea levels: melting glaciers lead to rising water levels in the oceans, which can cause coastal flooding. 2. Changes in atmospheric currents: changes in temperature in the Arctic can affect weather conditions in other parts of the world (disruption of climate patterns).
Economic consequences	1. Access to new resources includes the development of untapped oil and gas fields, mineral deposits, and fishing grounds. 2. Transportation routes: An open Northern Sea Route can provide a shorter route for shipping, which will have a positive impact on international trade. 3. Energy resources: the possibility of developing new energy sources, but with the risks of environmental disasters.
Social consequences	1. Displacement of indigenous peoples: possible interference with the traditional ways of life of indigenous peoples such as the Sami and others. 2. Migration and settlement: Infrastructure development may lead to increased migration of people to the Arctic regions.

Consequences of Arctic development	*Description*
Political implications	1. Territorial disputes: countries may argue for control over the Arctic because of its rich resources. 2. Geopolitical tensions: Competition for natural resources can lead to increased tensions between states, especially over maritime borders and access to resources.

Source: Alvarez, Yumashev and Whiteman (2020)

The economic impact of Arctic development on local communities can be both positive and negative. On the one hand, infrastructure projects such as the construction of ports, pipelines, airports, and new production facilities can create jobs and drive economic growth. Local communities can attract investment and develop businesses in sectors like transportation, logistics, construction, and the maintenance of oil, gas, and mining industries (Vaskivska *et al*., 2023). This, in turn, can increase local incomes and improve access to social services and infrastructure, including healthcare, education, and housing.

However, along with the potential benefits, there are numerous economic risks. Since indigenous peoples in the Arctic often depend on traditional subsistence activities such as fishing, hunting and reindeer herding, active exploitation of natural resources could disrupt these ecosystems and reduce the amount of resources available. The relocation of large industrial projects can alter environmental conditions, leaving local communities with a shortage of natural resources necessary to sustain their traditional ways of life. These changes to the natural environment can also impact agriculture, fishing, and hunting, key activities for the food security of indigenous peoples.

Social impacts of Arctic development may include changes in the lifestyle and cultural practices of local communities. In particular, the migration of workers from other regions and changes in the structure of the local economy can lead to social tensions, changes in traditional social ties, and even cultural loss. The integration of indigenous peoples into new economic structures can be difficult, as traditional social structures and ways of doing business are often incompatible with industrialised production methods. This can lead to alienation and social problems such as alcoholism, depression and social isolation, especially among young people who are unable to fully adapt to the new environment.

One of the significant environmental risks associated with Arctic development is pollution, which can negatively affect the health of local communities. Contamination of water, air, and land from oil and gas extraction, transportation, and other industrial activities can lead to serious health issues, particularly due to deteriorating water quality, the spread of diseases, and the overall decline of the environment (Bilyalov *et al*., 2025; Yermukhanova *et al*., 2017). Since the health of Arctic populations heavily depends on natural resources such as fish, wildlife, and water, a decline in the quality of these resources can result in severe social and health challenges.

The integration of indigenous peoples into economic activities is also a key consideration. In some cases, new infrastructure projects can offer indigenous

communities access to educational and employment opportunities. However, it is crucial to consider their traditions, way of life, and land rights. If these factors are not adequately addressed, local communities may face negative impacts on their social well-being, resulting in a loss of cultural identity and potential social conflicts.

The Arctic is known for extreme temperature fluctuations, ice cover, intense storms, and limited rescue capabilities, making it essential to develop and implement new technologies that can reduce environmental risks and ensure safe operations.

One of the key technological innovations is the new generation of vessels designed to operate efficiently in the Arctic. These vessels feature reinforced hulls specifically built to break through ice, along with modern navigation and safety systems tailored to Arctic conditions (Kondratenko, Kujala and Hirdaris, 2023). Such vessels are designed for enhanced manoeuvrability in icy waters and high stability during ice storms and strong winds. In particular, the introduction of autonomous vessels is crucial, as they can navigate the Arctic without the constant presence of a crew, reducing risks to personnel and enabling more efficient cargo transportation.

Production technologies in the Arctic also need innovation to extract natural resources, such as oil, gas, and minerals, efficiently and safely. One such innovation is subsea technology, which enables extraction at great depths beneath ice cover. This includes subsea work systems capable of drilling and producing from offshore fields even under the ice. In addition, the use of the latest remotely operated vehicles allows for complex operations at great depths or in hard-to-reach areas where traditional methods are impossible or too expensive.

Equally important are environmentally friendly technologies that minimise the risks of environmental pollution. For this purpose, environmentally friendly methods of oil and gas drilling and production are being developed that do not affect the marine ecosystem. This includes closed-loop production system technologies that reduce the risk of oil and chemical spills, as well as systems designed for efficient oil spill collection and clean-up. Given the high risk of pollution in the Arctic, it is also crucial to develop innovative systems for restoring ecosystems in the event of potential accidents. These can be specialised environmental robots or automated systems that can restore damaged areas without significant human intervention.

Innovative technologies for exploration and monitoring are also crucial for Arctic development. This includes the use of drones and unmanned aerial vehicles to monitor glacier conditions, track climate change, identify potential environmental threats, and assess resource availability. Satellite technologies for monitoring ice cover and predicting changes can also be employed to ensure efficient ship navigation and safe transportation in icy conditions (Mamasydykov *et al*., 2019).

Ensuring energy efficiency is also a key aspect of technological innovation for the Arctic. For instance, the development of renewable energy sources, such as wind and solar power plants, will decrease reliance on traditional energy sources and reduce the environmental impact of the region's development. Additionally, technologies for heat conservation and energy-efficient buildings tailored to Arctic conditions can help lower

energy costs and improve sustainability.

Finally, to ensure the safety and efficiency of operations in the Arctic, it is essential to implement real-time communication and monitoring systems that track all stages of production processes, enable quick responses to unforeseen situations, and facilitate coordination with other stakeholders in the region's development. This includes satellite systems that provide access to data on environmental conditions, ice cover, weather patterns, and the status of technical facilities.

Overall, the development of the Arctic is crucial for the global economy, as the region holds significant natural resources that can meet the energy and raw material demands of global markets. However, alongside these economic opportunities, there are significant environmental challenges due to the region's vulnerability to climate change and human activity. Therefore, it is essential to adopt a balanced approach to Arctic development that considers not only economic interests but also effective environmental protection and support for local communities.

This requires the development and implementation of a sustainable natural resource management strategy, investment in environmentally friendly technologies, the establishment of international legal mechanisms to protect the environment, and securing funding for eco-friendly projects. Supporting local indigenous communities, integrating scientific research, and continuously monitoring environmental changes are also vital components of ensuring sustainable development.

In conclusion, achieving a balance between economic growth and environmental protection in the Arctic demands a comprehensive approach that considers not only business interests but also long-term environmental impacts. Through international cooperation, responsible investment, and the adoption of innovative technologies, we can ensure the sustainable development of this unique region without compromising its natural environment.

Discussion

The Arctic region, recognised for its rich natural resources and strategic position between Europe and Asia, stands at the forefront of global economic interest. With its vast reserves of oil, natural gas, minerals, and biological resources, the Arctic has the potential to be a major player in meeting the global energy and raw material demands. However, the development of this region is a multifaceted issue that involves not only economic opportunities but also significant legal, environmental, and geopolitical challenges. These challenges are not isolated but interconnected, requiring a holistic approach to ensure the region's sustainable development.

A central challenge in Arctic development is the integration of economic goals with environmental protection (Kovach *et al*., 2024). As Yang *et al*. (2022) emphasise, the region's energy potential, particularly in oil and gas, has placed it at the heart of global energy security discussions. However, the extraction of these resources in an environment as sensitive and harsh as the Arctic requires careful consideration of environmental impacts. The high costs of resource extraction, particularly in the face of

extreme climatic conditions and the need for specialised technologies, make the financial viability of Arctic projects uncertain (Divoky, Brown and Elliott, 2021). At the same time, the region's vulnerability to environmental degradation, such as oil spills, habitat disruption, and rising temperatures, calls for innovative approaches to mitigate the risks associated with resource extraction.

To strike a balance between economic and environmental priorities, international legal mechanisms must be strengthened (Faichuk *et al*., 2022). Young and Kim (2021) argue that the Arctic's environmental vulnerabilities require robust international legal frameworks that can both regulate resource extraction and ensure the protection of its delicate ecosystems. This requires not only existing regulations but also the creation of new, adaptive legal instruments that can address the evolving nature of climate change and technological advancements. Williams *et al*. (2021) further suggest that the integration of scientific research and innovative technologies, such as clean extraction methods and real-time environmental monitoring, can help mitigate the negative impacts of Arctic development. The need for continuous innovation in these technologies cannot be overstated, as they play a critical role in preserving the Arctic's ecosystems while enabling resource exploitation.

The geopolitical landscape of the Arctic is equally complex, with nations such as Russia, Canada, and the United States all vying for control over the region's resources and strategic passages. The competition for territorial rights and resources is not a new issue, but the changing dynamics in the region, particularly the melting of sea ice and the opening of new shipping routes, have escalated these tensions. Territorial disputes, especially in areas like the Arctic continental shelf, continue to create diplomatic friction between states. According to Buckley (2023), these conflicts are often rooted in differing national interests, with countries seeking to secure their energy resources and control over critical trade routes.

While the rivalry between Russia, the United States, and Canada is well-documented, this study suggests that the challenge is more nuanced. The shift towards multilateral diplomacy and international cooperation is necessary to resolve these territorial disputes and create an environment conducive to sustainable development. The Arctic Council has already begun this work, but its limited mandate, particularly in the areas of economic regulation and enforcement, highlights the need for a stronger and more coordinated international effort. The role of non-Arctic states, such as China, must also be considered, as their increasing investments in the region pose additional challenges and opportunities for international cooperation. Shijin, Wenli and Qiaoxia (2023) argue that Arctic and non-Arctic states alike must collaborate to develop common environmental strategies, especially in light of climate change and the increasing demand for Arctic natural resources.

An often overlooked aspect of Arctic development is the rights of Indigenous peoples who have lived in the region for centuries. These communities rely heavily on the land and natural resources for their subsistence, and the influx of resource extraction activities can disrupt their traditional livelihoods. While economic development can offer significant opportunities for local communities, particularly in terms of employment and infrastructure, their interests must be fully integrated into the decision-making process.

Nilsson and Larsen (2020) stress that involving Indigenous populations in the planning and implementation of Arctic projects can lead to more equitable and sustainable outcomes. Indigenous knowledge systems, which have been developed over generations of living in the Arctic, offer valuable insights into sustainable resource management that can complement scientific and technological innovations.

This integration of local perspectives is essential not only for social equity but also for environmental sustainability. Indigenous peoples are often the first to experience the negative effects of environmental degradation, yet they are also some of the most effective stewards of the land (Andreitsev *et al*., 2024). Protecting their rights and ensuring their participation in decision-making processes can help ensure that economic growth in the Arctic does not come at the cost of social stability or environmental health.

To navigate the complex challenges of Arctic development, a comprehensive and integrated approach is needed. The solution lies in balancing economic goals with environmental preservation and social equity. As Lamarre *et al*. (2021) suggest, achieving this balance requires a multi-layered strategy that includes:

1. International Legal Reforms: Strengthening and expanding existing legal frameworks to create enforceable international standards that govern economic activities in the Arctic, ensuring both resource extraction and environmental protection. This includes enhancing the role of the Arctic Council and other international organisations in creating and enforcing regulations.
2. Technological Innovation: Investing in technologies that can minimise environmental impacts, such as renewable energy sources, energy-efficient production methods, and advanced oil spill containment systems. The development of new technologies in mining, drilling, and transportation that reduce ecological footprints is essential for mitigating the region's vulnerabilities.
3. Local and Indigenous Community Involvement: Ensuring that Indigenous peoples and local communities are integral to the planning and decision-making processes. This includes not only respecting their land rights but also incorporating their traditional knowledge into modern resource management strategies.
4. International Cooperation: Enhancing diplomatic relations and fostering cooperation between Arctic and non-Arctic states to address territorial disputes and develop common environmental strategies. A cooperative approach can help resolve tensions and promote joint efforts in preserving the Arctic ecosystem.
5. Investment in Sustainable Infrastructure: Developing infrastructure that meets the region's growing demand for resource transportation while minimising environmental impact. This includes the construction of eco-friendly transport networks and the modernisation of Arctic ports to accommodate the growing volume of goods transported via the Northern Sea Route.

The importance of international cooperation in this process cannot be overstated. As Raspotnik, Grønning and Herrmann (2020) emphasise, the Arctic's challenges are global and require coordinated international efforts to address them. By aligning economic, legal, environmental, and social goals, the Arctic can be developed in a way that benefits all stakeholders while preserving its unique ecosystem for future generations.

The development of the Arctic presents both unprecedented opportunities and significant challenges. By integrating scientific research, technological innovations, and Indigenous knowledge, and by fostering international cooperation, it is possible to create a sustainable and inclusive framework for Arctic development. This framework must balance economic growth with environmental protection and respect for Indigenous rights, ensuring that the Arctic can contribute to global prosperity while maintaining its ecological integrity. Sustainable Arctic development is not just a regional issue — it is a global imperative that requires collective action, innovation, and a commitment to the long-term health of both the Arctic and the planet.

Conclusions

The study highlights the Arctic's critical role as a source of natural resources and its strategic importance for the global economy. While the region's oil, natural gas, minerals, and biological resources hold significant potential for energy security and economic growth, realising these benefits involves navigating substantial economic, legal, and geopolitical challenges. The high costs associated with resource extraction and transportation in the Arctic's extreme conditions, along with the legal complexities of international agreements like the United Nations Convention on the Law of the Sea, underscore the need for a balanced approach to development.

To achieve sustainable development in the Arctic, it is essential to reconcile economic interests with environmental protection and respect for Indigenous rights. A key challenge lies in striking a balance between resource extractions for global energy markets and safeguarding the region’s fragile ecosystems. Moreover, the interests of Indigenous communities who depend on the Arctic's natural environment must be considered alongside corporate interests. Policies should ensure that local populations have a voice in decision-making processes and that development does not disrupt traditional livelihoods.

A clear policy roadmap is necessary to guide the Arctic’s development. This includes fostering international cooperation to resolve territorial disputes, establishing robust environmental standards, and investing in innovative technologies that reduce the ecological footprint of resource extraction. Governments and corporations must prioritise sustainable practices, such as energy-efficient production and environmentally friendly transport methods, to minimise adverse impacts. Additionally, legal frameworks should be strengthened to ensure that the benefits of Arctic development are shared equitably, with particular attention to the rights and interests of Indigenous peoples.

Ultimately, the Arctic’s potential can be fully realised through a coordinated approach that balances economic growth, environmental sustainability, and social responsibility. This will require continuous investment in technological innovation, enhanced international collaboration, and comprehensive environmental monitoring to ensure the Arctic remains a resource for future generations without compromising its ecological integrity.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*
Conceived and designed the research or analysis	Yes	Yes
Collected the data	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
Critical revision of the article/paper	Yes	Yes
Editing of the article/paper	Yes	No
Supervision	No	No
Project Administration	No	Yes
Funding Acquisition	No	No
Overall Contribution Proportion (%)	50	50

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